A PHILOSOPHICAL

INVESTIGATION

OF THE

Origin, Viciſſitude, and Power

OF

STEAM

EMPLOYED IN A

FIRE-ENGINE

WITH

A candid and familiar Explanation of the Parts, Powers, and true Conſtruction of that ingenious MACHINE:

AND

Demonſtration that the Force of the STEAM is the direct and efficient Cauſe of the Aſcent of the PISTON in the Cylinder: And alſo the Occaſion of all Evacuation therein by ſnifting, &c. contrary to the miſtaken Opinion of many Engineers, &c.

From whence the true Rationale and Conſtruction of that noble Machine may be eaſily deduced, many Errors corrected, and Improvements made.

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PREFACE.

AS *the inhabitants of all countries that produce coal, lead, tin, copper, and other ſubterraneous commodities, by experience find that ſuch wealth is unattainable without the uſe of Fire-Engines: And moreover, when we conſider that all the kingdoms on earth are benefited by theſe commodities, we may conclude, that all men are more or leſs intereſted in the improvement of that machine; and would be more or leſs injured, were ſuch contrivances to loſe their effect from any cauſe whatever.*

That they will loſe their whole effect, I am happy to think can never happen: But that they now, in a neighbourhood whoſe every thing almoſt depends upon them, fall ſhort of the effects they did produce, cæteris paribus, *in their primitive ſtate, is too certain; for they do not now make above two-thirds of the number of ſtrokes in a given time, they then did. This deficiency in a matter ſo ſerious, is ſomewhat alarming; and probably is occaſioned by the engineers of that neighbourhood not recurring to the true principle on which it was at firſt conſtructed, and on which its perfection ever will depend: This I have long conjectured; becauſe innovations have been introduced quite re-*

pug-

pugnant thereto. But what puts it beyond a doubt, is their declaration, that the elaſtic force of the ſteam cannot be the cauſe of the aſcent of the piſton; for its force is (ſay they) no way equal to the preſſure of the impending atmoſphere on the top of the piſton:— (Nay, I have been told that it could not puſh up the weight of a man:) And that the aſcent of the piſton is occaſioned by the weight of the pump-rods; the ſteam only ſerving to be condenſed when the piſton has attained its greateſt elevation, and thereby makes the neceſſary preparation for the deſcent of the piſton. §

This peremptory declaration, corroborated by the ſpirit of wagering, and elated altercation, which I forbear to mention, of a poſſe *of connoiſſeurs that ſtickled in the affair, who proteſted they were authorized to ſay, That their opinion was alſo the opinion of all the engineers, principal mathematicians, and philoſophers in the neighbourhood. Theſe, together with the anxiety I was under for the languiſhing ſtate of the true principle on which the nobleſt piece of mechaniſm that ever was conſtructed by man depends, laid me under an indiſpenſible neceſſity of laying before a candid Public an explication of the parts of the Fire-Engine, their manner of acting, and an inveſtigation of the properties of ſteam, to aſcertain the prime and ſole mover in that ſtupendous contrivance:— Which is the buſineſs of the following pages.*

§ *An aſſertion quite unphiloſophical and abſurd, becauſe it is making a power that is clearly direct and effectual, precarious and occult; and ſubſtituting for cauſes mere conſequents.*

INTRO-

INTRODUCTION.

IN order to avoid, as much as poſſible, in the following pages, the perplexity that would devolve on the ſubject, the reader, and myſelf, by a detail of philoſophical argumentation, I beg leave to inſert the following axioms or ſelf-evident truths, to recur to as criterions in the courſe of the demonſtrations, *viz.*

I. "THAT a body always perſeveres in a ſtate of reſt, 'till by ſome force it be made to change its ſtate.

II. "THAT the change of motion, or of reſt to motion, is proportional to the force impreſſed, and is produced in the right line in which that force acts.

III. "THAT action and re-action are equal with oppoſite directions, and are to be eſtimated always in the ſame right line.

IV. "THAT a thing cannot be and not be at the ſame time.

That

V. " THAT a whole is greater than a part thereof,

VI. " THAT from nothing, nothing can ariſe.

VII. " THAT no effect can be greater than its cauſe."

THESE, notwithſtanding they are inviolable truths, and co-eval with creation itſelf, many have neglected to initiate into their minds. The want of which has given birth to the ideas of a perpetual motion, annihilation of friction, gaining power without a proportional loſs of time, and the whole group of mechanical impoſſibilities, that have ruined the intellects as well as fortunes of thouſands; and alſo loaded the ineſtimable ſcience of mechanics with unjuſt reproach.

I THEREFORE, in this place, (altho' it may ſeem foreign to the buſineſs of this pamphlet) beg leave to requeſt all gentlemen that have machines of any kind to erect, to examine the propoſitions their engineers lay down relative to the end propoſed; and if it cannot be attained without violating ſome of theſe axioms, to deem ſuch propoſitions abſurd and iniquitous.

N. B. I AM here to inform the reader, that I do not mean to be underſtood as ſcrupulouſly exact in the following particulars, *viz.* the weight of a gallon of water, the height and diameter of the jack-

head

head pump, the weight of the pump-rods, the quantity of friction on all the parts of the engine, *&c. &c.* For theſe depend on circumſtances too precarious for peremptory calculations, ſuch as the ſituation of the jack-head pump-well, the materials the pump-rods are of, the ſmoothneſs or aſperity of the cylinders, *&c.* the degrees of purity and coldneſs of the water, *&c. &c.* I therefore have eſtimated them in round numbers only; and indeed ſome of them have been taken by ſuppoſition, whence they may vary ſomething from the real quantities produced or required in *particular* engines: But ſuch variations never can overturn the principles deduced from the following arguments.

lead pump, the weight of the pump-rods, the quantity of friction on all the parts of the engine, &c. &c. For these reasons we [illegible] precautions [illegible] dimensions of the [illegible] the pump-rods are of, the friction [illegible] the cylinders, &c. the weight of [illegible] of the water, &c. [illegible] them in actual practice only; and [illegible] them have been [illegible] may vary something [illegible] does be required [illegible] engines [illegible] additions [illegible] ces from the following arguments.

A

Philoſophical Inveſtigation, &c.

THAT the ſteam employed in a fire engine is originally water, I believe all men are ſo well convinced, that to ſpend time in illuſtrating that point, would be altogether unneceſſary. I ſhall therefore proceed to aſcertain the rationale of the propagation of ſteam, its power, and viciſſitude, in that agency.

1ſt, THEN, Water having extenſion and reſiſtance, muſt be material: And what material bodies conſiſt of cannot be better explained than in the words of Sir ISAAC NEWTON—"It ſeems highly probable, ſays he, that GOD, at the firſt formation of matter, gave the globular atoms, or primitive particles thereof, a ſolid, impenetrable contexture, even ſo hard as never to wear or break in pieces: No ordinary power being able to divide what God himſelf made one in the firſt creation. And this, continues he, is manifeſt, becauſe while theſe continue entire, they may compoſe bodies of one and the ſame

nature and texture in all ages, by new aſſociations; but ſhould they wear away, or break in pieces, the nature of things depending on them would be changed. Whence, bodies being of the ſame nature now as formerly, it follows that theſe atoms are immutable."

WATER then being material, muſt, according to this moſt rational theory, be compoſed of globular atoms. And as there is not a poſſibility of globular bodies coming into contact with one another's entire ſurfaces, we may conclude, theſe interſtices will be filled with that ſort of æther which is found to permeate all other bodies: The known properties of which are a proportional degree of dilation to the degree of heat applied, and of contraction or re-action when the cauſe is taken away; which properties perfectly coincide with the idea we entertain of elaſticity. Now, as the fluid, which occupies the interſtices of the primitive particles of water, is ſuſceptible of a proportional degree of dilation, to that of the action of fire applied; it follows, that theſe primitive atoms are thrown out of the ſphere of their attraction by that dilation; and that the force they fly off with, is capable of being increaſed to the laſt finite degree. And alſo, that when the cauſe ceaſes,

ceaſes, the fluid and particles being indiſſoluble, they will, by re-action, aſſume their former mode and contexture.

WHENCE it alſo follows, that ſteam may be generated of vaſt elaſtic force, by extraordinary means, even capable of throwing up a ton weight on the ſurface of an inch; but as the one hundred and fortieth part of that degree of elaſtic force is ſufficient to give and uphold a proper degree of motion in a fire engine, it is attainable by ſuch ordinary means as are every day practiſed in common fire engines; as will appear by what follows. For in the boiler of every fire engine there is a valve or ſteam-clack, which ſhuts downward, and is loaded with at leaſt one pound on every ſquare inch of the aperture it covers. When the ſteam is to be prepared for working the engine, this clack is drawn up for ſome time, to let the common air (which inſinuated itſelf into the boiler amongſt the water, and by other means) eſcape, for that will come off with leſs heat than generates ſteam of the proper elaſtic force to anſwer the demand of the engine. When the air and ſoft ſteam are gone off, (which an experienced engine-keeper eaſily perceives by the colour of the ſteam, &c.) the clack is let down,

down, and if the ſteam throws it up, it is in perfection; and the trigger or regulator, which prevents the ſteam from entering the cylinder when ſhut, is drawn open, and the engine begins to operate: The particulars of which, I beg leave to defer until I have eſtimated the force of the ſteam when it throws up the clack.—Now, as the common air has been let out of the boiler, and the aperture ſhut by letting down the clack, the atmoſphere is excluded the inſide of the boiler, and therefore in courſe will compreſs the outſide with an intenſity of about 15 lb. on every ſquare inch of ſurface that is pervious thereto; which I ſhall, in this caſe, ſuppoſe is the top of the boiler only; and alſo that it is a boiler of 15 feet diameter. Whence we find that the preſſure on the top of the boiler will be upwards of 165 tons; and that the top would ſink under ſuch a load, when we conſider the frailty of its conſtruction, appears abſolutely certain, were it not for the elaſtic force of the ſteam within;*

which

* Whence it is abſolutely neceſſary to keep the elaſtic force of the ſteam and preſſure of the atmoſphere, within about 1-15th of the ſame tenor at all times when the ſteam clack is ſhut, as the neglect of which has demoliſhed many boilers. And this depending entirely on the judgement and integrity of the engine men, it ought to determine owners to take none into that employ, but men of experience and diligence.

which at the time it throws up the clack, certainly is 1-15th ſtronger than the preſſure of the atmoſphere, (*cæteris paribus*); becauſe as every ſquare inch of the top of the boiler is preſſed with 15 lb. the clack being a part thereof muſt alſo ſuſtain that preſſure in proportion to its dimenſions: And as it had alſo a load of 1lb. to every ſquare inch of the aperture it covers put upon it, whenever the ſteam throws it up, contrary to the efforts of theſe reſiſtances, it muſt be 1-15th ſtronger than the peſſure of the atmoſphere at that inſtant of time; as *per* axiom 1, 2, 3, 4, and 7. The force of the ſteam, when it puſhes up the valve or clack, being now aſcertained, I return to explain its particular operations and viciſſitude in the cylinder, &c. viz. The regulator or trigger, which prevents the ſteam entering the cylinder when ſhut, being drawn back, and the piſton at its point of greateſt elevation, which is occaſioned by the atmoſphere inſinuating itſelf into the cylinder, when the engine has ſtood ſtill ſome time; for as the parts cool they contract, and thereby make larger interſtices between the cylinder and piſton, and the pins and ſockets of the various cocks thereto belonging, than when warm.

By theſe means, I ſay, the atmoſphere getting poſſeſſion of the inſide of the cylinder, will, with reſpect to moving and detaining the piſton, neutralize itſelf, by puſhing as much below the piſton as it preſſes above it; and the pump rods and their appendages being uſually ſomewhat heavier than the piſton and its acceſſories, in proceſs of time they ſink, and the piſton attains its greateſt point of elevation, or nearly ſo. The piſton and other parts being in this poſition, when an engine is put a-going, the current of ſteam is let in until the parts are warmed, and the air which poſſeſſed the cylinder is driven out at the horſe-foot valve and ſnifting-clack, which is another proof of the ſteam being ſtronger than the atmoſphere, (*per* axiom 7, &c.) for no effect can be greater than its cauſe. When the parts are warmed and the air driven out, the regulator or trigger is ſhut, and inſtantly the injection cock opens, and a ſtream of cold water is let in from near the bottom of the cylinder, and being preſſed by a high column, throws it againſt the bottom of the piſton with great force, and makes it fly off in all directions in a copious ſhower. Whence, as the æther which fills the interſtices of the primitive particles of water has, by the action of the fire, thrown them out of the ſphere of their attraction or coheſion; and as that

elaſtic

elaſtic force ceaſes when the cauſe is removed (as has been premiſed) the cold water, from its known properties of extinguiſhing fire, cannot fail of producing the effect, if thrown in in a proper quaintity. This needs no further comment, as it is verified by daily experience. And thus, from the above theory, we conceive the following rational idea of ſteam being again converted into water, viz. As the elaſtic force of the fluid, which occupied the interſtices of the atoms, is abated ſo far as to contract it into 1-2893d part of the ſpace it occupied when able to overcome the atmoſphere, as has been alledged from the experiment of Mr Henry Brighton; the atoms will then fall again within the ſphere of one another's attraction; and the fluid being indiſſoluble, as well as the atoms, and being ſurrounded by them, muſt be pent up in its former cells. And thus, upon the whole, the expanſion and contraction of water, which in its expanded ſtate is called ſteam, and all its viciſſitudes, are, I hope, accounted for in a ſatisfactory manner.

I BEG leave to return then to the piſton, where it has obtained its greateſt depreſſion by the impulſe

pulſe of the atmoſphere on its top, in conſequence of a partial vacuum being made in the cylinder. Now, to form a juſt idea of the quantity of the preſſure on the top of the piſton, we are to attend to the following particulars, viz. What the aggregate of the columns of water lifted; exceſs of weight of the pump-rods, when compared with the weight of the piſton; and the reſiſtance by friction on all the parts of the engine amounts to in weight or reſiſtance. For which purpoſe we muſt deſcend to particulars; and ſhall ſuppoſe then the main pump to contain a column of water 12 inches diameter and 70 fathoms high, and the jack-head pump column 50 feet high and 6 inches diameter; the friction on all the parts 10 hundred weight, and the exceſs of weight of the pump rods 6 hundred weight; whence they will ſtand thus:

	ton.	*cwt.*	*ſt.*	*lb.*
A column of water 70 fathoms high and 12 inches diameter, at 10 lb. per gallon — — — —	8	18	5	7
A 50 feet column of ditto, 6 inches diameter, at 10 lb. per gallon	0	5	2	7
Friction on all the parts — —	0	10	0	0
Relative weight of the pump-rods	0	6	0	0
Aggregate — — Tons	10	0	0	0

The piſton having attained its greateſt depreſſion, with conſiderable velocity, and overcome the reſiſtance (of theſe particulars) to the amount of 10 tons, it follows, that the preſſure of the atmoſphere on the top of the piſton, when it deſcended, was at leaſt 10 tons,* which preſſure muſt in courſe continue to act in that direction and quantity, ſo long as the cylinder remains air-tight; and that it will continue air-tight until the piſton aſcends, as well as it did until it deſcended, we may with certainty conclude, becauſe it is performed in as ſhort a ſpace of time, and the apertures are then all ſhut againſt the air as before; whence it undoubtedly follows, that the piſton in its aſcent is lifted, or puſhed, (if it moves with the ſame velocity it deſcended) by agents, whoſe powers are more than 10 tons. And that we may be able diſtinctly to diſcern what theſe agents are, I beg the reader's permiſſion to take a look back on the cauſes of that reſiſtance, in order to diſcover how far by re-action they can aſſiſt the aſcent of the piſton. 1ſt, Then, I enquire into the re-action of the columns of water in the pumps, which from the peculiar conformation of the valves and lifters, can have no re-action at all on the piſton, becauſe

* No notice is here intended to be taken of the preſſure which overcomes the imperfectneſs of the vacuum.

A vacuum can not be ſaid to be imperfect in practice if the steam can be condensed

in every lifting pump there is a box fixed a little below the greateſt deſcent of the working box or lifter. This under box has a valve or clack which opens upwards, and admits a column of water to paſs through it ſufficient to fill the vacancy the lifter or moving box makes when drawn up: And as ſoon as the lifter or moving box begins to deſcend, the valve on the top of the fixed box ſhuts, and thereby prevents the water, which had followed up the lifter, from making its eſcape.——The lifter then has its valve, which alſo opens upwards, thrown up by the reſiſtance of the column of water ſuſtained by the under box: And, as water is (by the Florentine experiment, &c.) found to be ſo far incompreſſible as not to yield to human power, it follows, that the column of water above the lifter will be ſuſtained by the column of water that is between the lifter and under box; and that the under box is the baſis on which they both reſt until the lifter riſes again. Whence, as I ſaid before, the column of water in the pumps can have no reaction on the piſton; and therefore the ſum of 9 tons, 18 cwt. 5 ſt. 7 lb. which they required to liſt them when the piſton deſcended, remains in preſſure of the atmoſphere on the top of the piſton, without abatement.

2dly, Let us enquire into the ſtate of the power which was uſed to overcome friction, viz. 10 cwt.

and

and ſee whether that can in any manner aſſiſt the aſcent of the piſton.

THE immediate reſult of this enquiry is, that it can have no re-action at all, becauſe friction in mechanics is an annihilation of power; whence the preſſure with which the top of the piſton was loaded, viz. 10 cwt. to overcome the friction when the piſton deſcended, muſt alſo continue entire.

3dly, LET us enquire into the internal ſtate of the cylinder, in order to eſtimate the reſiſtance of the ſteam, &c. after condenſation. And this appears briefly to be ſo nearly uniform, as to occaſion no material difference of reſiſtance from the ſetting out of the piſton, until it arrives at its greateſt depreſſion; becauſe the abatement of reſiſtance, which the diſcharge of the water at the top of the pumps, &c. occaſions, is compenſated by a proportional accelerated velocity in the deſcent of the piſton, when a proper injection is made.—The reſiſtance of the medium, through which the piſton paſſes in its deſcent, being uniform, or nearly ſo, therefore precludes the idea of its reſiſtance being of any viſible uſe in the aſcent of the piſton, relative to overcoming the reſiſtance above-eſtimated.

4thly and laſtly, THE weight of the pump rods

fall

fall under conſideration with regard to their re-action. The reſult of which is, that if the lifters did not meet with reſiſtance, on account of the apertures being much ſmaller than the cavities of the pumps, and thereby wire-draw the water, their whole relative weight ought to be deducted, viz. 6 cwt. but as the interruption the lifters meet with from that cauſe is at leaſt 1-6th, we ought to deduct to that amount.

HAVING thus fairly eſtimated every article which could be ſuppoſed to aid the aſcent of the piſton, by dint of re-action, and found that the whole amount of the preſſure, which was laid on the top of the piſton, for lifting the columns of water, and overcoming all manner of friction, and a part of the relative weight of the pump rods, in all 9 tons, 15 cwt. beſides the reſiſtance of friction when the piſton aſcends, remains to be overcome by a direct cauſe, otherwiſe the piſton never can aſcend, and the effect of the engine is at an end.—Now, as there is not a poſſibility (every thing being as before premiſed, and as they are indeed always found in practice) of any other agent interpoſing to puſh up the piſton except the ſteam, if the piſton does aſcend when the regulator opens (which is a well-known fact) it inevitably follows, (*per* axiom 1, 2, 3, 4, 5, 6, and 7) that the elaſtic force of the ſteam is the direct cauſe thereof; and

and that the part the relative weight of the pump rods performs in the pulling up the piſton, falls ſhort even of paying the credit (if I may uſe the expreſſion) which they took of the preſſure on the piſton to cauſe their aſcent. Hence it is certain, that the pump rods, as well as the beam and all other denominations of members of the machine, or counter-balance thereto annexed, are altogether paſſive, and neither have, nor can communicate any motion but what is communicated to them by the elaſtic force of the ſteam when the piſton aſcends, and by the partial vacuum it occaſions when that elaſticity is annulled by condenſation.* The ſteam therefore, with the utmoſt propriety, ought to be conſidered as the prime and ſole mover in a fire-engine; and whoſoever do not go upon this principle in the conſtructing and working of fire-engines, it is very evident, go upon a falſe one, and their work therefore at beſt will be imperfect.

HAVING in the above demonſtration, to avoid confuſion, omitted a recapitulation of the force of the ſteam in the boiler, when it puſhed up the gauge clack or valve, which was fairly proved to be 1-15th ſtronger than the atmoſphere; and as the fires are kept in an uniform ſtate, or nearly ſo, it cannot fail of being nearly of the ſame tenor when it

* The preſſure of the atmoſphere in this caſe being only a conſequent.

it enters the cylinder; and as boilers are, or ought to be, calculated to ſupply their cylinders with a convenient quantity of ſteam, of nearly the ſame elaſtic force from the opening of the trigger or regulator to the time of its ſhutting, we have teſtimony in this way alſo of the ſteam puſhing up the piſton by its peculiar properties: For as the quantity of ſteam which puſhes againſt each ſquare inch of the ſurface of the bottom of the piſton, is a pound ſuperior to the preſſure of the atmoſphere on each ſquare inch of the ſurface of the top of the piſton, and the top and bottom ſurfaces are, undoubtedly, equal; we will find the reſult of this ſuperiority in a cylinder of 55 inches diameter, (and ſuch a one an engine to overcome the reſiſtance occaſioned by the imperfectneſs of the vacuum, and to work the above premiſſes, muſt at leaſt have) amounts to 21 cwt.*

THIS much I have thought neceſſary to add, as it clearly evinces, that the ſteam is prepared to do the work I have aſſigned it in the preceding demonſtration.

HAVING now, as far as is neceſſary to produce conviction in every reaſonable and honeſt mind, ex-

* Balance in favour of the ſteam, to make up any deficiency that will attend its variation in elaſtic force or heat (in a well-conſtructed engine that is properly kept) and ſo thereby give a convenient velocity to the piſton.

explained the true principle of a fire-engine, I ſhall next, according to promiſe, mention a few particulars relative to the improvement of that machine, by way of advice to engineers, viz.

1ſt, That they would eject from ſervice all ſlenched boilers, becauſe they ſuffer the ſteam to cool by being held where the action of the fire does not reach.

2dly, That they will alſo eject all iron plate covers, becauſe they not only let ſteam eſcape, but ſuffer the air to cool it.

3dly, That they will, for the ſame reaſon, eject all reſervoirs for ſteam between the boiler and cylinder, and do every thing that will preſerve heat.

4thly, That they will contrive to make the pipes, which convey the ſteam from the boilers to the cylinder, as ſhort, and to make as few angles as poſſible.

5thly, That they will calculate, to the utmoſt nicety, the ſize of theſe pipes, and the aperture which the regulator ſhuts, in order to vend the ſteam, without wire-drawing it too much, or by being too large, to vend it faſter than the boiler can ſupply, and thereby give the preſſure of the atmoſphere on its top purchaſe to break it in.

6thly, That they will place the jack-head reſervoirs higher in engines, which have wide cylinders, than they do in thoſe of ſmall ones, in order

to promote a proper injection, for that depends more on the height of the column than on its diameter.

7thly, That they will be careful to prevent the hot water mingling with the water in the jack-head pump-well, an inconvenience too often practiſed; and alſo, that every precaution be taken (when the piſton deſcends) to keep the injection water cold, as well as to keep the ſteam hot when the piſton aſcends.

8thly, That they will eject all covers to the noſe of the ſteam-pipe, which are fixed in a horizontal poſition, notwithſtanding there are ſide vents left for the ſteam, becauſe ſuch covers break the current of ſteam in the ſame manner as a board placed between the end of the trough of a water-mill (at right angles to the current) and the wheel, which would greatly impair the effect, if not quite deſtroy it: Whence, I am convinced, that if the engineers, who have introduced ſuch covers and inconveniences as above-mentioned, had not unfortunately abandoned the true principle of action in the fire-engine, they never could have been capable of ſuch abſurdities.

And finally, I beg leave to requeſt ſuch engineers to recur to theory, founded on a ſound principle, as well as to practice, and then their own good-ſenſe will ever determine what ought to be done to give that ſtupendous piece of art its beſt [illegible] and maximum effect.